FINAL REPORT

SINBAHD PROJECT:
SOFTWARE USER MANUAL

INO 99-5217SM RFI N/A

Presented to:

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TABLE OF CONTENTS

1. INTRODUCTION 2
2. OVERVIEW OF THE GUI 2
3. OPERATION MODE DIALOG SCREEN 10
4. ICCD DIALOG SCREEN 14
5. SPECTROMETER DIALOG SCREEN 17
6. BACK-SCATTER DIALOG SCREEN 18
7. WEATHER DIALOG SCREEN 21

1. INTRODUCTION

The purpose of this document is to provide a description of the software graphical user interface (GUI) developed for Sinbahd. The Sinbahd software has been developed using Microsoft Visual C++ environment (MVC++, version 6.0 Professional Edition). All graphical controls (buttons, edit boxes, drop-down list) are from the MVC++ environment, except for the graphical windows which are ActiveX controls from National Instrument Measurement Studio.

The software organization is composed of three different MVC++ modules:

1. SinbahdCore module (.dll, dynamic link library): Synchronizes the acquisition processes, performs the data pre-processing and processing, memorizes the acquired data as well as the different operation mode parameters. Note that this module is independent of any hardware specificity. Thus, any change made to the hardware (for example a new spectrometer model, camera model, etc...) would have no impact on the SinbahdCore module.

2. SinbahdHardware module (.dll): Controls the operation parameters of the different hardware components connected to the system. These components include the laser, the ICCD camera, the spectrometer, the transient recorder, the delay generator, the visibility sensor and the weather station. Note that SinbahdHardware module depends on SinbahdCore.

3. Sinbahd module (.exe): Controls the graphical user interface of the software. That module depends on both the SinbahdCore module and the SinbahdHardware module.

It is not the purpose of this document to provide the complete description of the software architecture design. Nevertheless, the source code documentation for each function of the Sinbahd software can be found inside the source files.

2. OVERVIEW OF THE GUI

The GUI developed for the Sinbahd program consists in a main dialog screen from which both spectral and back-scatter acquisitions can be performed at the same time using the

Start, *Stop* and *Pause* control buttons. The main dialog screen also allows to call different sub-screen from which the different operation mode parameters may be set.

The Sinbahd main dialog screen and its upper menu bar are both displayed respectively in Figure 1 and in Figure 2. The remainder of this section will now describe the functionality of each various control of the Sinbahd main screen. These different controls are numbered and pointed by arrows in Figure 1.

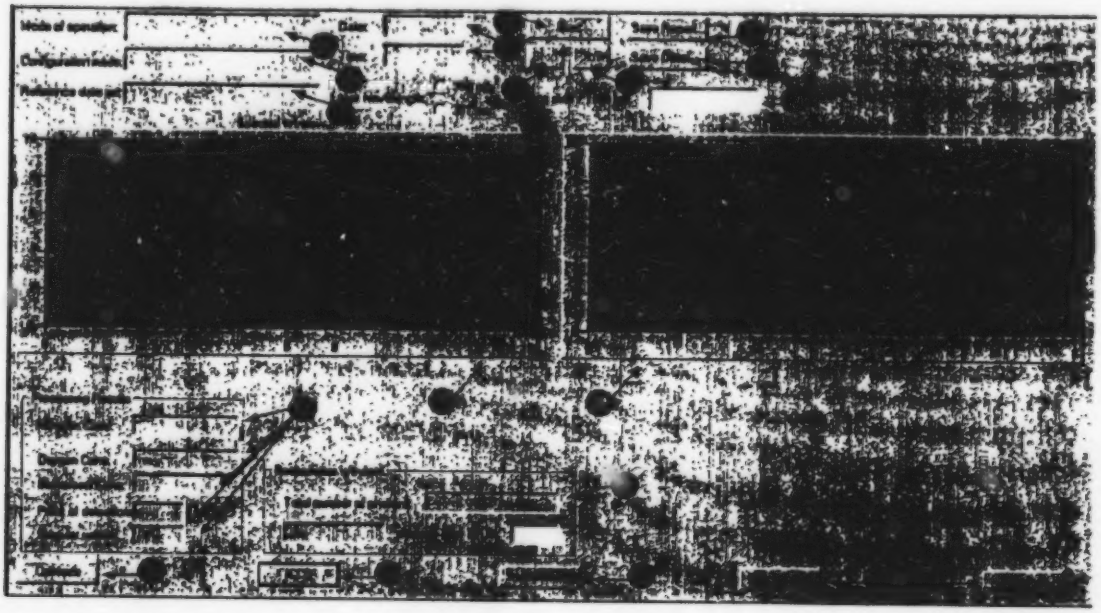

Figure 1 Main Dialog Screen.

Figure 2 Main Menu Bar.

1. This box displays the mode of operation of the system for the current session. The mode of operation may be changed by using the *OpModes* item of the upper menu bar (see Figure 3) or by right-clicking directly in the box (a shortcut that accesses the *OpModes* menu). The possible modes of operation are:

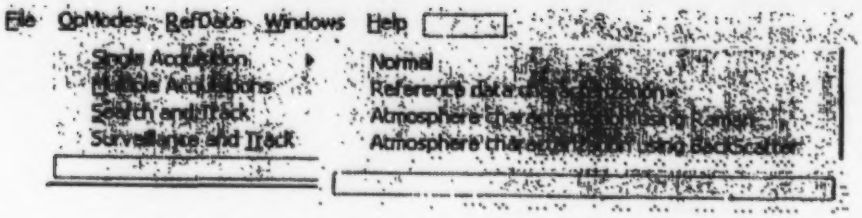

Figure 3 OpMode menu for choosing the mode of operation.

a) **Single Acquisition : Normal**: The system will shoot the number of laser pulses set by the user in the *OpMode* sub-dialog (see Section 3). Once the acquisition is over and the raw data are collected, the pre-processed data are displayed in both the BackScatter and the Spectral graphical windows (items 12 and 13 in Figure 1). Note that the different pre-processing options may be changed in the *OpMode* sub-dialog. In addition to graphical results, numerical processing results are also displayed above the two graphical windows. Obviously, a reference data set (see item 3 below) must be loaded so that the processing (i.e. the fitting with the spectral signature of a known bioaerosol) can be performed. Otherwise, the Sinbahd program will ask the user to select one before starting an acquisition

b) **Single Acquisition : Reference Data Characterization**: The system operates such as for the normal single acquisition mode except that instead of processing the acquired spectral signal, it uses it in order to create a new reference data set which could be used for future acquisitions with processing. Thus, that mode of operation is used to characterize and to memorize the spectral profile of known bioaerosols present in the atmosphere during the acquisition. Once characterization is over, the GUI will ask the user to select a filename where to save the new reference data set and to indicate the reference bioaerosol concentration in ACPLA units (Aerosol Content Per Liter of Air). By default, all reference data sets are saved in the Sinbahd\ReferenceData directory.

c) **Single Acquisition : Atmosphere Characterization using Raman**: That mode is used to estimate the spectral atmosphere attenuation parameter by using the information provided by the Raman signals rather than the extinction coefficient indicated by the visibility sensor. Section 3.4 of document INO 99-5217SP RF N/A explains how the atmosphere attenuation

is estimated using the Raman signals. As a result, a new atmosphere attenuation parameter is available for the user in the *OpMode* sub-screen (see Section 3). That attenuation parameter is time-tagged in order to facilitate multiple characterizations at different times of the session.

d) **Single Acquisition : Atmosphere Characterization using BackScatter**: That mode is used to estimate the spectral atmosphere attenuation using the signal returned from the back-scatter channel. When operating in that mode, the system tries to estimate the atmospheric attenuation by fitting an exponential function over a delimited section of the back-scatter return[1]. For the fitting algorithm, the range limits may be set by the user in the OpMode sub-screen (see item 14, Section 3). As a result, a new atmosphere attenuation parameter is available for the user in the *OpMode* sub-screen (see item 13, Section 3).

e) **Multiple Acquisition**: The system performs multiple sequences of single acquisition and displays the graphical processing results between each acquisition. The maximum number of sequences that can be processed within the same session can be set by the user in the *OpMode* sub-screen. Note that the processing results above the spectral and back-scatter windows are now replaced by a time logged window which displays the concentration of bio-agent as a function of the system time (see Figure 4). The X-axis width of the time-logged window may be easily adjusted by right-clicking anywhere inside the window. A small dialog than appears (see Figure 5) that asks the user to set the total width (in hours, minutes and seconds) of the window.

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[1] Note that in regard to the backscatter preprocessing options (see section 3), that mode of operation requires that the background correction and the range correction are checked while the atmospheric correction is unchecked.

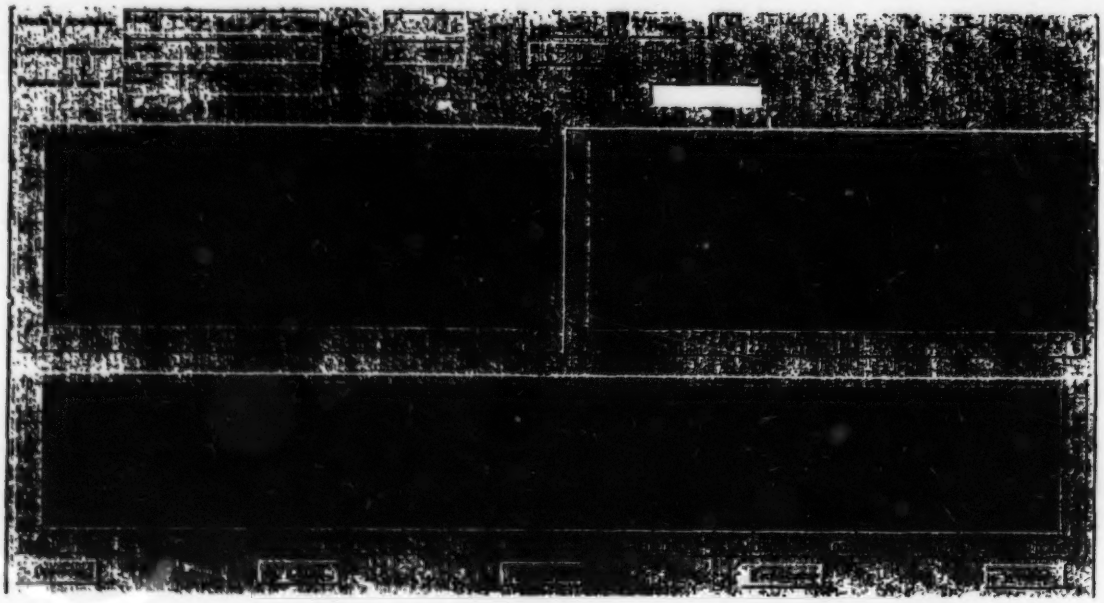

Figure 4 Main Dialog Screen (if the operation mode is different than Single Acquisition).

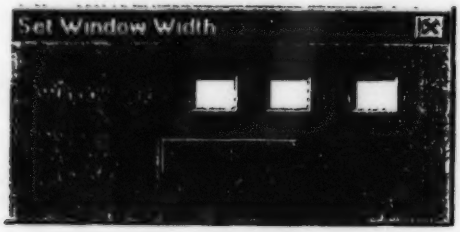

Figure 5 Window width dialog screen.

f) **Search and track**: The system operates as in the multiple acquisition mode except that between each acquisition, Sinbahd searches for the presence of bio-agent in the atmosphere. When the system locates a potential cloud in the back-scatter window, the probed spectral cell (see the description of the back-scatter graphical window) is relocated over it before the beginning of the next sequence of acquisition. Otherwise, the range position of the probed spectral cell is incremented or decremented by the search increment value set by the user in the *OpMode* sub-screen.

g) **Surveillance and Track**: That mode is very similar with the Search and Track mode except that the probed spectral cell remains at its position as long as a potential cloud is not detected.

2. This box displays the name of the active configuration mode of the system. A configuration mode for operating the system is defined as the whole parameters that can be changed by the user in any dialog or sub-dialog of the Sinbahd GUI. Each time that a new sequence of acquisitions is started, the software makes sure that no parameter has changed since the last acquisitions. If one or more parameters changed, a new time-tagged configuration is created and becomes the active one. A right-click inside the configuration box lets the user select any configuration from the list of all available configurations. Once a configuration is selected, the system automatically changes its setting so that they correspond to the active configuration. Once a session is over, the user can save the list of all configurations in a configuration file by using the *Save As...* item of the *File* menu. In the same way, a list of configurations already saved on file may be opened by using the *Open...* item of the same menu. Note that by default, all configuration files are saved and opened from the Sinbahd\ConfigData directory.

3. This box displays the active reference data set for the processing (see item 1b) above). By default, no reference data set is provided by the software. The user must choose one of them by either right-clicking inside the box or by using the *RefData* menu (see Figure 2). By default, all reference data sets are saved and opened from the Sinbahd\ReferenceData directory.

4. These boxes display the date and the system time.

5. These radio boxes allow the user to load the calibration data files associated with laser wavelengths 308nm and 351nm. Those calibration data files are read from the Sinbahd\CalibrationData directory.

6. This *Start* button begins an acquisition (WARNING: This will cause the laser to shoot).

7. The *Stop* button aborts any acquisition immediately. This button stops the laser.

8. The *Pause* button momentary pauses the sequence of acquisitions. Acquisitions can be restarted by using the *Start* button.

9. The *Save Report* button allows the user to save in a file (in text format) all acquired acquisitions vectors (fitted data, spectral signal and back-scatter signals) as well as their different operation mode parameters.

10. The *Save Data* button allows the user to save on file (in binary format)) all acquired acquisitions. Those data are then readable by the *VirtualSinbahd* application (not documented).

11. This box displays the current acquisition number on the maximum number of acquisitions (e.g. 3/10) and the time left for the acquisition on the total estimated acquisition time (e.g. 15s./30s.).

12. This graphical window displays the acquired spectral data and the resulting fitted spectral profile as a function of the wavelength values (nm). The acquired spectral signal is preprocessed according to the options set on the *OpMode* sub-dialog. Each signal may be optionally displayed depending on the option selected by the user on the bottom part of the *Spectral* item of the *Windows* menu[2] (see Figure 6). From the same *Spectral* item, the user can set the tracking mode of the spectral window to zoom in or zoom out[3]. He can also customize both the X and Y axes by calling the Set Axis... sub-dialog (see Figure 7). Finally, the user can also save the raw vectors that are displayed on the graph in column format on a text file.

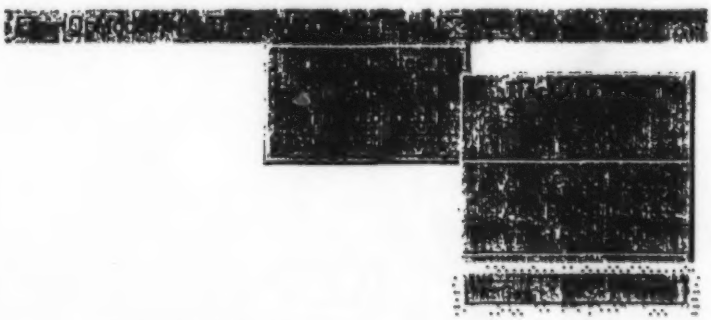

Figure 6 Spectral item of Windows menu

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[2] Note that a right-click anywhere inside the spectral graphical window corresponds to a shortcut for accessing the *Windows* menu.

[3] Note that a double-click inside the spectral window corresponds to a shortcut for zooming out.

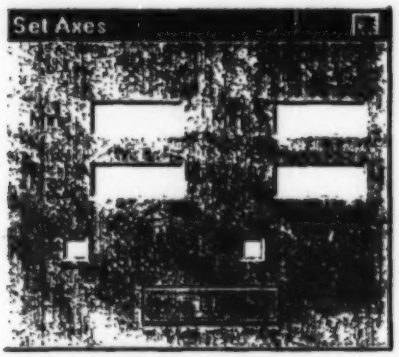

Figure 7 Set axes dialog screen.

13. The back-scatter window displays the acquired back-scatter range profile as well as the position and width of the probed spectral cell (red cursors). The range limits for the probed spectral cell are also indicated by the blue cursors. Note that the settings selected by the user in the *OpMode* sub-dialog are those used to preprocess the back-scatter range profile. The X axis of the graph corresponds to the range (m) while the Y axis is in arbitrary units and depends on the preprocessing parameters. As for the spectral window, the user is allowed to customize both axes, to select the tracking mode of the window and to save on file the raw vector displayed on the window. These options are available either via the *Backscatter* item of the *Windows* menu or by right-clicking anywhere inside the back-scatter window (see Figure 8). The user should notice that when *Cursor* tracking mode is selected (which is the default mode), he can reposition the probed spectral cell anywhere inside the range limits (the blue cursors) only by dragging and dropping the red cursors. The blue cursors are fixed and may only be repositionned when changing the range limits values in the *OpMode* sub-dialog.

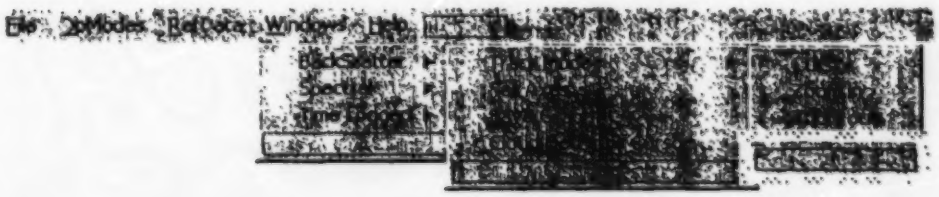

Figure 8 Back-scatter item of Windows menu.

14. These read-only boxes display the processing results when the operating mode is Single Acquisition : Normal (see item 1a) above). These results give information on the derived concentrations for O_2, N_2, and for biological agent associated with the current reference data set (see item 3 above). They also indicate the probability of detection for the biological agent and the presence or not of singular values for the SVD (*Singular Value Decomposition*) fitting. Usually, singular values are indicative of an ill-posed problem (chaotic estimation of coefficients, given model and data) or if parts of the model are linearly dependent.

15. This set of boxes display information about the photon counting signal. The total number of photons counted is displayed as well as the number of photons detected after a bin number specified by the user. Valid values for the bin number are in the interval [1,8190].

16. This button calls the operating mode dialog screen (see Section 3).

17. This button calls the ICCD dialog screen (see Section 4).

18. This button calls the spectrometer dialog screen (see Section 5).

19. This button calls the back-scatter dialog screen (see Section 6).

20. This button calls the weather dialog screen (see Section 7).

3. OPERATION MODE DIALOG SCREEN

This dialog is used to set the values of some generic operating modes that do not depend on any hardware components. In addition, some processing options and parameters can also be set in that dialog. Note that all changes that are made in the operation mode dialog box are taken into account only if the user accepts them by clicking the OK button. Otherwise, the Cancel button returns to the previous configuration.

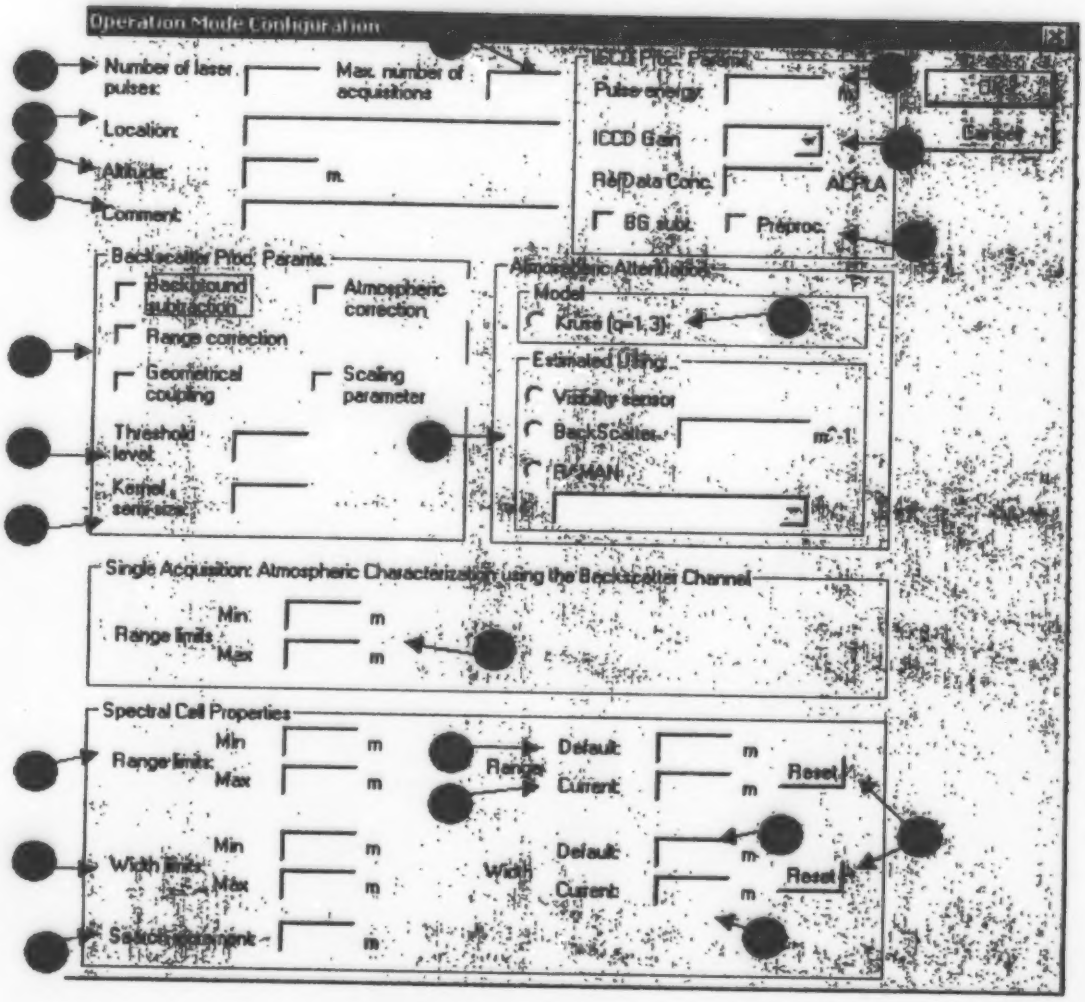

Figure 9 Operation mode dialog screen

1. This edit control sets the number of laser pulses that will be fired. The number of laser pulses determines both the number of ICCD and transient recorder acquisitions.

2. This edit control allows the user to enter a text comment about the physical location (country, city, etc…) of the acquisitions. That comment will be saved in both the configuration file and the full output report.

3. The user can set the altitude to which acquisitions are carried out in this edit control. The default altitude is 0 meter. When processing the acquisitions, the

altitude is used by the software for computing the atmosphere attenuation (see Section 3.4 of document INO 99-5217SP RF N/A).

4. The user can enter a general comment in this edit box. The comment will be saved in the full output report.

5. Except for the single acquisition mode, this edit control is used to set the maximum number of acquisitions. We recall that an acquisition does not correspond to a laser pulse, but rather to a predefined number of laser pulses after which the pre-processing and the processing are performed.

6. For the back-scatter signal pre-processing, the user can decide to apply or not different corrections (see Equation (17) in Section 3.5 of document INO 99-5217SP RF N/A. Thus, the range correction check box refers to parameter r^2, the geometrical coupling factor refers to $\xi_{bs}(r)$, the atmospheric correction refers to $t_{at}^2(\lambda_0)$ and the scaling parameter refers to the product $E_0 n_{pu}$. In addition, the background subtraction check box allows to subtract or not the background obtained from the back-scatter channel.

7. This edit control allows the user to set the threshold used by the software to merge the photon counting and the analog signals into a combined signal. The threshold is a percentage of the maximum saturation value for the photon counting signal. 0% percent of saturation indicates that only the analog signal is used while 100% of saturation indicates that only the photon signal is used.

8. This edit control allows to set the kernel semi-size used to determine the junction between the analog and the photon counting signals.

9. This edit control allows to set the desired laser pulse energy for the laser. If, for any reason, the Sinbahd software is unable to read the laser pulse energy returned from the laser, the software will use that value to process the different acquired signals.

10. This drop list is VERY important for the software since it allows the user to enter the gain setting value of the ICCD camera. The gain setting is used when pre-processing the spectral signal (see parameter G in Equation (20), document INO 99-5217SP RF N/A). Note that the gain setting that is set in that dialog has NO impact on the gain setting which is really set on the ICCD. This is due to a

limitation of Andor camera which does not allow to control the gain setting by software.

11. These two boxes allow the user to apply or not a background subtraction for the spectral signal and to apply or not the different spectral pre-processing correction factors defined by Equation (5) of document INO 99-5217SP RF N/A.

12. For now, the only atmospheric model that is available for the processing is the Kruse model, with q=1.3 (see document INO 99-5217SP RF N/A for details about the atmospheric model).

13. These radio boxes allow the user to choose how the spectral atmosphere attenuation factor $\alpha(\lambda)$ must be computed. Thus, the quantity $\alpha(\lambda)$ can be determined using the atmosphere attenuation that is returned by the visibility sensor, can be estimated from the back-scatter return, or can be estimated from the Raman signals of the nitrogen and/or oxygen[4]. In that latter case, the user must select one of the atmosphere attenuation estimations already available in the drop-down list located below the two boxes. Note that these estimations can be produced when the acquisition mode is set to *Single: Atmosphere Characterization Using Raman*. For the estimation from the back-scatter return, the acquisition mode must be set to to *Single: Atmosphere Characterization Using Backscatter* (see the main dialog for the explanations about the different acquisition modes).

14. When the system operates in mode *Single: Atmosphere Characterization Using Backscatter*, these two edit boxes are used to set the range limits for fitting the back-scatter curve.

15. These edit boxes are used to set the minimum and maximum limits for the range position of the probed spectral cell. Note that these limits also correspond to the search limits for the *Search and Track* acquisition mode.

16. These edit boxes are used to set the minimum and maximum limits for the width of the probed spectral cell.

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[4] For more details concerning the estimation from the Raman signals, see Section 3.4 of document INO 99-5217SP RF N/A

17. This edit box allows to set a new default position for the probed spectral cell. Note that the cell is repositioned to its default position only when the user clicks the *Reset* button located on the right.

18. This read-only edit box displays the actual range position for the probed spectral cell.

19. This edit box allows to set a new default width value for the probed spectral cell. Note that the cell is only reset to its default width when the user clicks the *Reset* button located on the right.

20. This read-only edit box displays the actual width of the probed spectral cell.

21. These two buttons reset the spectral probed cell to its default position and width values.

22. This edit box sets the range search increment for translating the probed spectral cell during *Search and Track* acquisition mode. Note that the increment can be either positive or negative.

4. ICCD DIALOG SCREEN

The ICCD dialog screen controls the operation parameters of both the intensifier camera (Andor's ICCD camera) and the delay generator (model DG535 from SRS) that are connected to the Sinbahd system. The ICCD dialog screen, such as it appears when the user presses the ICCD button of the main dialog, is shown in Figure 10.

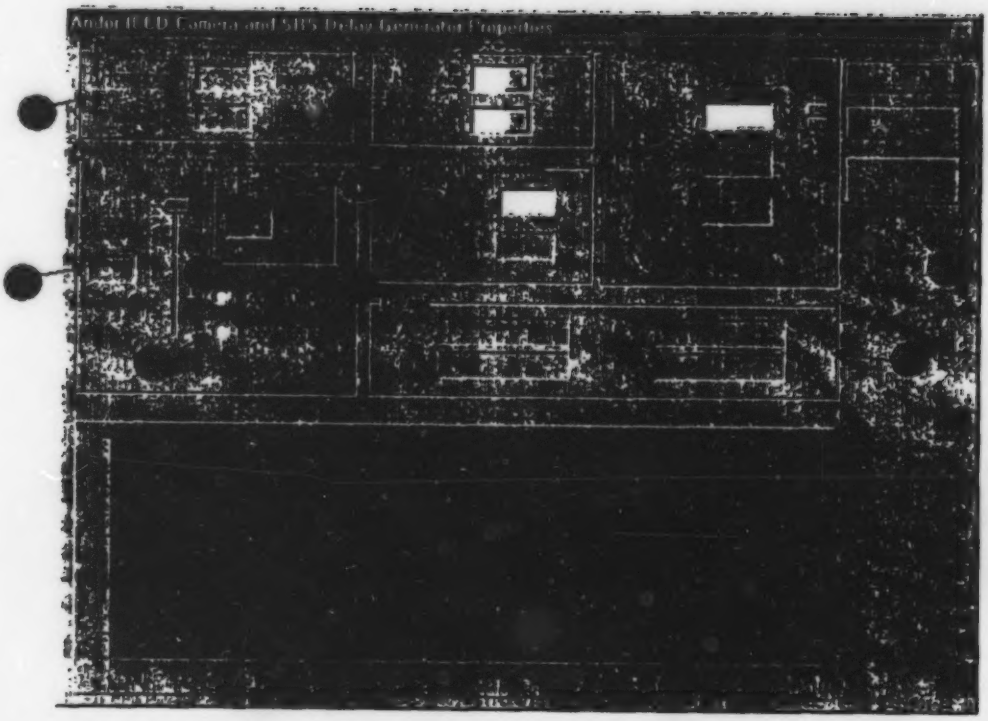

Figure 10 ICCD Dialog Screen

1. These two read-only boxes display the horizontal and vertical CCD dimensions of the detector in pixels. These dimensions are those read from the detector.ini file loaded by Andor's library at program initialization. The detector.ini text file may be edited by the user in order to change the dimension of the detector.

2. These two drop-down lists are used to set the horizontal and vertical shift speeds of the CCD.

3. This read-only box displays the temperature setting (in Celcius) at which the detector should be cooled or warmed. The temperature setting may be changed by dragging the vertical slider until the required value appears in the box.

4. These radio boxes switch the detector's cooler ON or OFF. When the cooler is ON, the detector's temperature is raised or lowered while the temperature setting is not

reached. Otherwise, the detector's temperature gradually reaches the ambient temperature.

5. This read-only box displays the current detector's temperature. The temperature is updated every five seconds.

6. This edit box allows the user to set the exposure time of the CCD.

7. This read-only box displays the number of acquisitions as computed from the number of laser pulses that is set in the Operation mode dialog screen (see Section 3). Because of the background subtraction and of the two trigs that are necessary to start the laser, the number of ICCD acquisitions is defined as $N_{ICCD} = (N_{LASER} * 2) + 2$.

8. This edit box is used to set the external trigger level (in Volts) of the delay generator. The external trigger level must be in the interval [0, 2.5] Volts. The external trigger level might also be incremented by using the two arrows of the spin control located on its right.

9. These read-only boxes display the actual range position and width of the probed spectral cell as computed from delays A and B of the delay generator. The range position and the width are given respectively by $(A_{SEC} \times c)/2$ and $(B_{SEC} \times c)/2$,, where A_{SEC} and B_{SEC} are the delays A and B in seconds and where c is the speed of light.

10. These four read-only boxes display the current delays that are set on the delay generator. Delays A and B define the position (A) and width (B) of the probed spectral cell (see item 9 above) while delays C and D are used to position the background spectral cell for the background acquisition. The user can manually adjust delays A and B by dragging the cursors of the back-scatter window in the main interface (see Section 0). As for the delays A and C, the delay C is always set to 2 milliseconds (half of the operational exposure time) while delay D (width of the background cell) is set equal to delay B (width of the probed spectral cell).

11. This button is used in order to start spectral acquisitions that are independent of the whole Sinbahd system. In other words, the Start button of the ICCD dialog screen has no impact on the transient recorder of the back-scatter channel (see Section 6).

12. This graphical window displays the raw acquisition vector acquired by the Start button.

5. SPECTROMETER DIALOG SCREEN

The spectrometer dialog screen allows to control the spectrometer connected to the Sinbahd system (model MS260i from Oriel). The different functionalities allow to open and to close the mechanical shutter, to select one of the three gratings as the active one, and to change the wavelength position of the active grating. Figure 11 shows the spectrometer dialog screen such as it appears when the user presses the Spectrometer button from the main dialog.

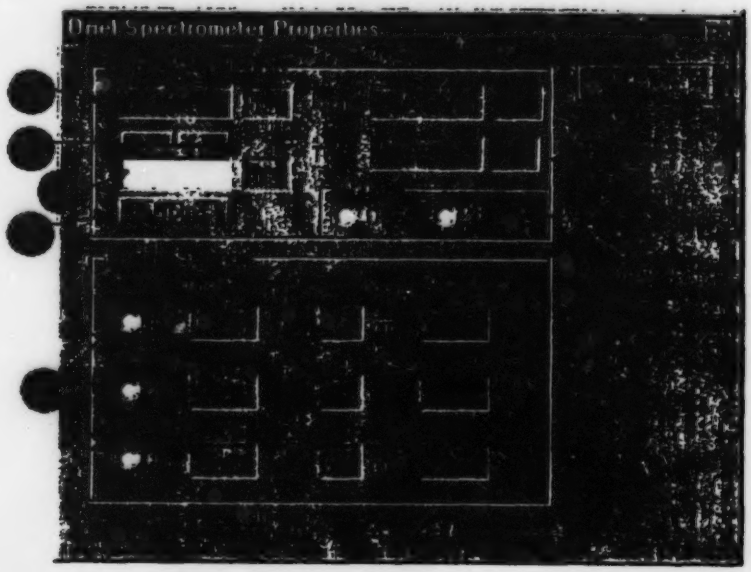

Figure 11 Spectrometer dialog screen

1. This control displays the current center wavelength position for the active grating.

2. This spin control allows the user to change the center wavelength position of the active grating by one increment. That increment can be either positive (right arrow) or negative (left arrow). For each grating, the size of the increment (in nm.) is determined by the wavelength calibration matrices loaded by the software (see

parameter λ, Table 10, Section 6.1, Document INO 99-5217SP RF N/A). We recall that those matrices (one for each grating) enumerate all wavelength positions which were calibrated for the Sinbahd Project. Note that the wavelength drive starts to move as soon as one of the arrow is pressed.

3. This edit control allows the user to specify a new center wavelength position. Note that the wavelength drive will not start to move until the user presses the Goto button.

4. When pressed, this button starts the movement of the wavelength drive toward the wavelength position indicated by the user in the edit control. Note that the spectrometer will stop at the closest wavelength position found in the wavelength calibration matrices.

5. These two controls display the minimum and maximum wavelength positions of the active spectral window. The spectral window width (max. - min.) of each grating corresponds to its span value provided by Oriel (see Table 2, Section 5.2.3, Document INO 99-5217SP RF N/A).

6. These two radio buttons are used to open and to close the mechanical shutter.

7. These three radio buttons are used to select one of the three gratings. When one of them is pressed, the spectrometer moves its wavelength drive toward the smallest central wavelength position associated with the specified grating (see the wavelength calibration matrices for the valid ranges of each grating). Before changing from one grating to another, the software will always make sure that the mechanical shutter is closed. Otherwise, the software will first close the shutter, then will move to the new grating, and finally will reopen the shutter. This procedure is followed in order to protect the ICCD camera connected with the spectrometer.

6. BACK-SCATTER DIALOG SCREEN

The back-scatter dialog screen controls the optical transient recorder which is connected to the Sinbahd system (Licel's Lidar-transient recorder TR 40-160). In addition to the setting of the different operation mode parameters, this dialog also allows to perform back-scatter acquisitions that are independent of the whole Sinbahd system (i.e.

acquisitions that only imply the transient recorder and that do not depend on the laser or the ICCD camera).

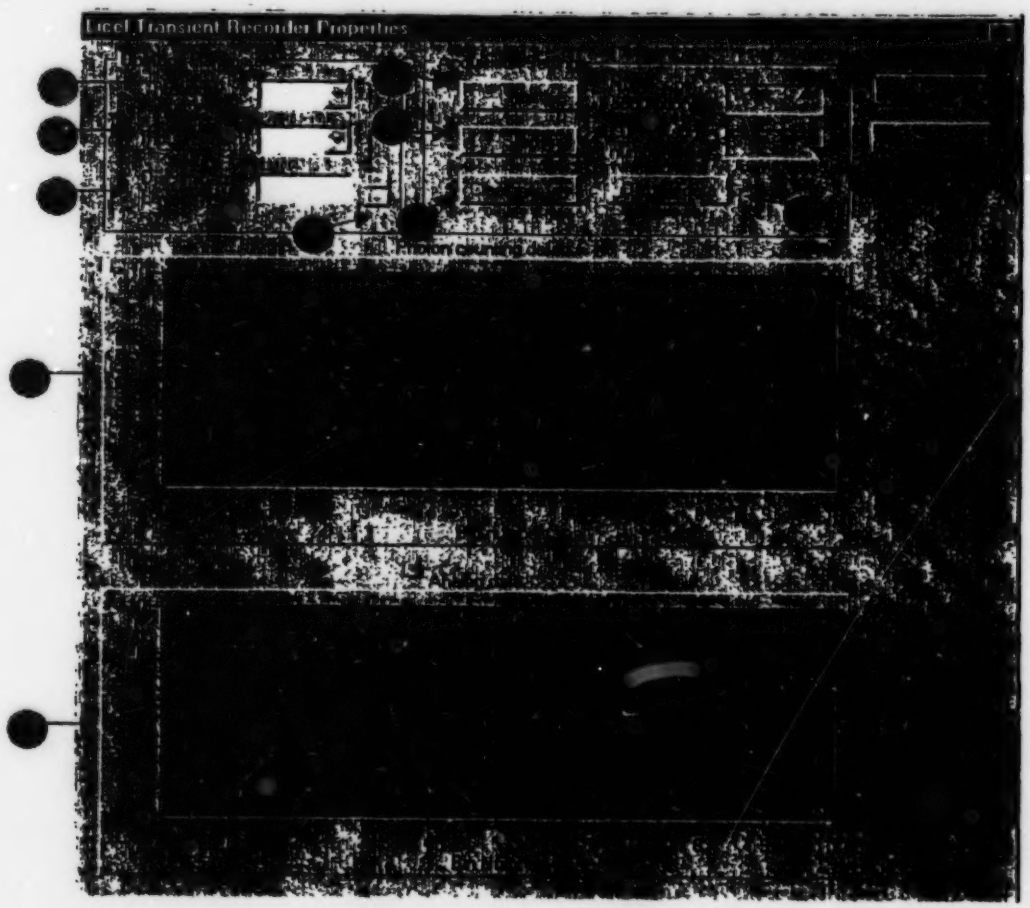

Figure 12 Back-scatter dialog screen

1. That drop-down list is used to select the threshold mode that defines the increment between discriminator levels. The threshold can be low or high. In the low threshold mode the discriminator level 63 corresponds to -25mV while in the high threshold mode it corresponds to -100mV. Note that such as for the other operation mode parameters (i.e. the input range and the discriminator level), a change brought to the threshold value will be taken into account only if the user presses the OK button. Otherwise, the Cancel button will restore the previous configuration.

2. That drop-down list is used to select the input range for the analog input. The available input ranges are -20, -100 and -500mV.

3. In this edit-box the user can enter a discriminator level value for the photon counting input. The discriminator level can be set in 64 steps between 0 and 63.

4. This spin control is used to raise or lower by one increment the discriminator level.

5. This button starts acquisitions that are independent of the whole Sinbahd system. The only requirement so that the transient recorder starts to record data (analog signal and photon counting signal) is that a trigger is connected to the transient recorder.

6. This button stops the acquisition process started with the Start button.

7. This button clears the accumulated data from both memories of the transient recorder.

8. This read-only box displays the number of accumulations that will be taken when the user presses the Start button from either the back-scatter dialog or the main dialog[5]. That number is always equal to the number of laser pulses set in the Operation Mode dialog screen (see Section 3).

9. This read-only box displays the current accumulation number.

10. This button is used to read memory A and to display its acquired signals (raw analog data and raw photon counting) in the two above graphical windows. Note that since memory B is dedicated to background reading, it is read only when the whole Sinbahd system is operated (i.e. when the laser is in operation).

11. This graphical window displays the photon counting data of memory A as a wavelength graph. The X axis of the graph corresponds to the bin number (from 0 to 8189) while the Y axis corresponds to the cumulated number of photon read in each bin.

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[5] In fact, the read-only box displays the number of accumulations recorded in EACH memory of the transient recorder. Thus, the total number of recorded accumulations is two times the number displayed.

12. This graphical window displays the analog signal of memory A as a wavelength graph. The X axis of the graph corresponds to the bin number (from 0 to 8189) while the Y axis corresponds to the cumulated millivolt values read in each bin.

7. WEATHER DIALOG SCREEN

The weather dialog screen displays information about the current visibility and the current weather conditions as read from the Belfort visibility sensor and the Rainwise weather station. In addition, the dialog allows the user to save in a file all logged data stored in the weather station computer interface.

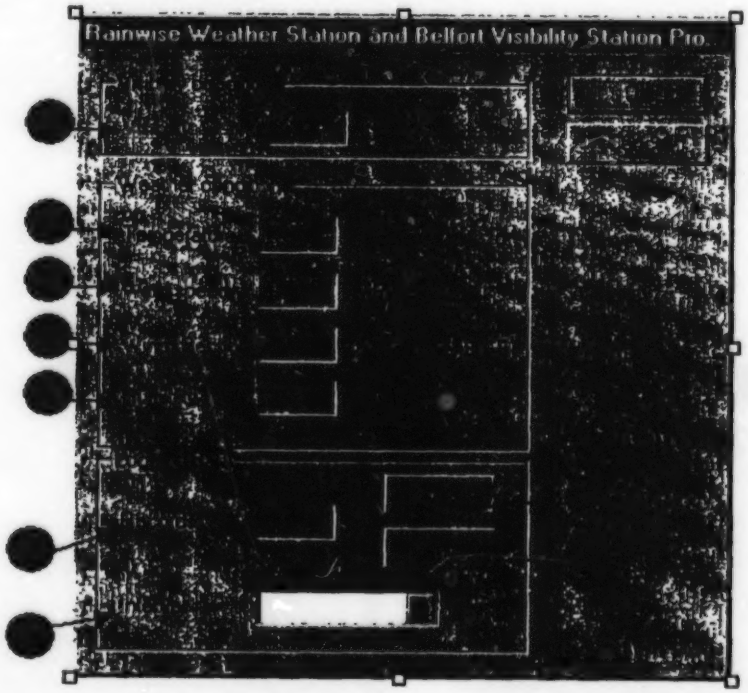

Figure 13 Weather dialog screen

1. This read-only box displays the current visibility conditions in kilometers.

2. This read-only box returns the current temperature in Fahrenheit.

3. This read-only box displays the current wind speed in miles per hour.

4. This read-only box displays the wind direction in degrees. North and east correspond respectively to 360 and 90 degrees.

5. This read-only box gives the relative humidity in percent.

6. This read-only box displays the total number of data logged into the computer interface memory of the weather station.

7. This drop-down list control allows the user to change the logging interval for the computer interface. The possible logging intervals are 1, 2, 5, 10, 15, 20, 30 and 60 minutes. Note that the selected logging interval will be activated only when the user click on the OK button. Otherwise, when the user chooses to click the Cancel button, his change is not taken into account and the previous logging interval value is preserved.

8. This button is used to clear all logged data from the computer interface memory.

9. This button is used to save all logged data on a ascii text file.